PROGRESS REPORT

Boundary Layer, Flux, and Soil Moisture Studies for NAME Including Deployment of a NOAA UHF Wind Profiler

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Summary

NOAA's Earth System Research Laboratory (ESRL) used a 915-MHz radar wind profiler and supporting meteorological instrumentation to provide data in support of the North American Monsoon Experiment (NAME) during the summer 2005 monsoon season. The data are to be used by NAME to meet the scientific objectives described in the NAME Science and Implementation Plan. Prior to the onset of the summer 2005 monsoon season, ESRL re-deployed a 915-MHz wind profiler with RASS virtual temperature profiling, a 10-m meteorological tower sampling standard meteorological parameters, instrumentation for the measurement of energy balance and radiation budgets, a GPS Integrated Precipitable Water Vapor system, a disdrometer for the measurement of raindrop size distributions, and a cloud ceilometer. The site was located near the small town of Estacion Obispo approximately 55 km southeast of Culiacan, 140 km northwest of Mazatlan, and 20 km from the Gulf of California. Site installation took place on June 28-29, 2005 with all instrumentation operational on June 29 at 2200 UTC. Although the site was installed and operational by June 29, low voltage problems delayed the start of some data acquisition to July 10. The site was removed on September 20. For the 83-day measurement period between June 29-September 20 we obtained data acquisition rates of 100% for the surface meteorology sensors, 86% for the 915-MHz wind profiler and RASS, 67% for the cloud ceilometer, 64% for the disdrometer, 96% for the GPS-IPW, 49% for the latent heat measurements, 69% for the sensible heat measurements, and 98% for the radiation budget measurements. Data processing and quality control for the 2005 data set should be completed by January 1, 2006. In addition to the meteorological measurements, ESRL staff began to analyze data obtained at the Estacion Obispo site during the summer 2004 monsoon season and prepared a paper summarizing these results for submission to the *Journal of Climate* for the NAME Special Issue.

1. INTRODUCTION

The North American Monsoon Experiment (NAME) is a process study aimed at determining the sources and limits of predictability of warm season precipitation over North America. During the summer of 2004, an international team of scientists carried out a major field campaign to develop improved North American monsoon precipitation forecasts. As part of the field campaign, NOAA ESRL deployed a 915-MHz wind profiler with RASS virtual temperature profiling, a 10-m meteorological tower sampling standard meteorological parameters, instrumentation for the measurement of energy balance and radiation budgets, a GPS Integrated Precipitable Water Vapor system, and a cloud ceilometer. Equipment from the Williams/White proposal, including a 449-MHz wind profiler, S-band radar, and a disdrometer, also operated at the Estacion Obispo site. The site was on the coastal plain, 20 km inland from the Gulf of California, between the cities of Culiacan and Mazatlan in Sinaloa, Mexico. During the summer of 2005, NOAA ESRL again deployed its suite of instruments, minus the 449-MHz wind profiler and S-band radar.

During the 2004 and 2005 experiments, data from all instrumentation were retrieved via a satellite link on an hourly basis. Hourly-averaged wind and virtual temperature profiles in addition to the 1-min averaged surface meteorological information were then made available on the World Wide Web through either graphical displays or via FTP transfers.

2. OVERVIEW OF FIELD PROGRAM

The NAME Research Permit was obtained on June 15, 2005 and the NOAA/ESRL equipment was shipped to Mexico on June 20. The NOAA/ESRL installation crew flew to Mexico on June 27, installed the site on June 28 and 29, and had all instrumentation operational on June 29 at 2200 UTC. Low voltage problems with our line power caused intermittent outages between June 30 and July 10. An electrician rewired the site on July 9th and 10th. All instrumentation became operational after this time.

At the site NOAA installed a wind profiler operating at 915 MHz. The radar was set up to collect vertical profiles of wind speed and direction and vertical velocity to altitudes of 3-4 km. The 915 combined with a Radio Acoustic Sounding System (RASS) provided virtual temperature profiles to 1-1.5 km. A Vaisala CT25K Laser Ceilometer provided reliable determinations of cloud heights to 7.5 km. A GPS Integrated Precipitable Water Vapor (GPS-IPW) System continuously monitored the atmospheric water using a GPS receiver and processor. A 10-m meteorological tower sampled the standard meteorological parameters including pressure, temperature, relative humidity, wind speed and direction, solar radiation, net radiation, and precipitation. The surface energy budget at the site was estimated using in-situ observations of the net radiative, latent, sensible, and ground heat fluxes. Downwelling solar irradiance was measured using a ventilated Eppley solar pyranometer (PSP) deployed at 2.0 meters above ground. When we analyzed the data collected by the downward pointing pyranometer (measures upwelling solar irradiance) during the NAME 2004 deployment we found that heat from the ventilator fan can get trapped near the top of the ventilator housing. This heat warms the body of the PSP and induces an artificial thermal gradient between the thermopile detector and the dome of the instrument. The anomalous thermal gradient causes

the instrument to underestimate the solar irradiance. For the 2005 deployment we substituted an Eppley Black and White solar pyranometer for the PSP. The Black and White pyranometer was deployed at 5.0 meters above the ground. Although this instrument should not be used in the measurement of global solar irradiance its thermopile detector design eliminates thermal offset errors of the type we found in the PSP. The overall effect of the pyranometer change should reduce the uncertainty in the estimated upwelling solar irradiance. We observed the upward and downward IR fluxes with ventilated Eppley pyrgeometers (PIR) mounted at 2.0 meters above ground. The sensible heat flux was computed using 20-Hz samples of the vertical wind component and temperature made by an Applied Technologies Inc. (ATI) sonic anemometer/thermometer. The latent heat and CO_2 fluxes were estimated using the ATI sonic vertical wind components and 20-Hz samples of humidity and CO_2 from a Licor-7500 open path gas analyzer. Ground heat flux measurements were made by a Radiation and Energy Balance Systems Inc. (REBS) HFT-3 heat flux plate buried 2.0 cm below the soil surface. We also obtained soil temperatures at depths of 5.0, 10.0, 15.0 and 60 cm using Campbell Scientific (CS) 107 temperature probes. Volumetric soil wetness fraction observations at 15.0 cm below the soil surface were made using a CS-616 Water Content Reflectometer. We calibrated the CS-616 by drying and weighing soil samples on site. A photo of the summer 2005 site is shown in Figure 1.

All instruments were shut down and packed for shipment on September 20.

Fig. 1. View of the summer 2005 NOAA ESRL site in Estacion Obispo, Sinaloa, Mexico.

2.1 Operational Summary

The following operational summary provides operations information for the Estacion Obispo site. The date listed represents that day during the experiment that an equipment check, data backup, equipment failure, change, or repair took place.

Operational Summary

June 20	Equipment trailer leaves for Mexico from Boulder, CO
June 27	Equipment trailer arrives at Estacion Obispo site
June 28	Site installation begins
June 29	Site installation completed
June 30	Installation crew returns to Colorado
July 6	Data backup and equipment checks, discover low voltage problem
July 9-10	Electrician rewires site, replaces disconnect box
August 3	Data backup and instrument checks
August 20	Power failure causes both UPS units to fail
August 24	Recharged UPS units and started data acquisition at 1500 UTC
August 26	Data acquisition computer shuts down because of software issue
September 1	Data acquisition computer problem corrected
September 20	Data backups and instrument checks, equipment shut down and packed up
September 21	Trailer picked up
September 26	Equipment trailer arrives in Boulder, CO

3. DATA PROCESSING

Level 1A processing of the radar and RASS data is accomplished by running the moments data through a modified Weber-Wuertz algorithm to remove obvious spurious data for wind speed, wind direction, and virtual temperature. Three different formats for each daily file are created. One of those formats is used to further process the data to level 1B. Level 1B processing involves visually inspecting daily wind and temperature files for inconsistencies not discovered with the Weber-Wuertz algorithm. Approximately 5 days of data are displayed at once. Time and height consistency checks are performed and the suspect data is marked as invalid. All 2004 wind profiler and RASS data have been processed and quality checked.

Level 1A processing of the meteorological data is carried out with an in-house algorithm to remove spurious suspect data and is flagged as such. Level 1B processing involves creating daily climatologies of the surface meteorological data and examining the data in time to try to identify any inconsistencies. All 2004 surface meteorological parameters have been processed and quality checked.

All summer 2005 data should be processed and quality checked by January 1, 2006.

4. ACTIVITIES

Post-processed dynamic and thermodynamic data from the NAME 2004 EOP began to be available in January 2005. While Hartten has extensive experience working with wind profiler data, Environmental Technology Laboratory (ETL) formats, QC, and averaging periods differ from what she is used to. Hartten spent some weeks reworking her FORTRAN library to handle the ETL data files. She then did some basic evaluation of the data which helped identify problems in the 449-MHz winds and the 915-MHz winds (detailed below), and discussed these results with engineers and scientists at ETL, Aeronomy Laboratory (AL) (as of 10/1/05 AL and ETL are part of ESRL), and Vaisala. She obtained initial results (discussed below) regarding the daily cycle at Estacion Obispo and presented these at the NAME Data Workshop in Mexico City. Late in March, she met with Dick Johnson and his colleagues at CSU to compare initial results and plan collaborations. For the rest of FY2005, Hartten continued to analyze data collected at Estacion Obispo during NAME 2004, with a focus on the daily cycle, and began a manuscript detailing the results. She also analyzed the daily cycle of winds measured by profilers at Puerto Penasco, Bahia Kino, and Los Mochis during NAME 2004. This work was done with Luna Rodriquez, a SOARS® (Significant Opportunities in Atmospheric Research & Science) protégé from the University of Puerto Rico.

During the NAME 2005 measurement period, King examined the incoming Estacion Obispo site data on a daily basis to evaluate the performance of the instrumentation and to identify any site problems. King made three trips to the site during the period for data backups and instrument checks and calibrations in addition to the site setup and removal trips.

King used the post-processed NAME 2004 wind profiler, RASS, and surface meteorological data to create monthly climatologies of wind and virtual temperature profiles. The time/height cross sections provided a first look at the daily cycles observed at the Estacion Obispo site.

Zamora spent a considerable amount of time in post processing and quality checking the soil moisture, soil temperature, and radiative, soil, latent, and sensible-heat fluxes from NAME 2004. The data set is unique as it provides a complete picture of the surface energy budget over a part of the sub-tropical coastal plain. As described in Section 2, all of the parameters used to calculate the surface energy budget have been measured rather than estimated, including the sub-surface temperature, flux, and moisture measurements. That makes this a very unique data set. Zamora also participated in the NAME 2005 site installation and removal.

5. RESULTS

For the 84-day measurement period between June 28-September 20 we obtained data acquisition rates of 100% for the surface meteorology sensors, 86% for the 915-MHz wind profiler and RASS, 67% for the cloud ceilometer, 64% for the disdrometer, 96% for the GPS-IPW, 49% for the latent heat measurements, 69% for the sensible heat measurements, and 98% for the radiation budget measurements.

Most data were made available in near real time on the NOAA/ESRL Regional Weather & Climate Applications web page. The page was updated hourly and included a 24-hr time series of profiler winds, RASS virtual temperatures, and surface meteorological parameters. Graphical representations of these data allowed ESRL scientists to assess the performance of the equipment in near real time and enabled those involved with NAME to evaluate immediately the existing meteorological conditions.

Initial comparisons of EOP-mean wind profiles from the 915-MHz and 449-MHz systems at Estacion Obispo clearly showed that the 449-MHz winds looked very different from the 60- and 105-m profiles from the 915-MHz profiler. Further work revealed three issues: (1) Radio Frequency Interference (RFI) is pervasive in the 449-MHz band, making it hard for our standard processing to pick spectral peaks, (2) there appears to have been a flaw in the E-W 449-MHz beam's connection, reducing height coverage and smearing the spectra, and (3) an incorrect calibration in the 449-MHz instrumentation has led to incorrect height calculations. Paul Johnston (CIRES), working with Jim Jordan (ESRL) and the raw data from both the 449 MHz and S-band systems, was able to compare bright band heights during precipitation events and compute a correction factor to solve (3). Jordan and Raisa Lehtinen (Vaisala) ran a day's worth of raw 449-MHz data through a beta version of multiple peak-picking software being developed by Vaisala, and found that it did a better job of extracting reasonable wind values from the raw data. We have a copy of that software, and believe it would be possible to run all the raw 449-MHz data through that processing and, by carefully comparing the results with the 915-MHz data in regions of overlap, extract reasonable wind profiles from the data. Since the 449-MHz profiler was funded through the Williams and White grant for precipitation work, not winds, this would be an "extra". We prepared and submitted a mini-proposal for this possible exercise to OGP/CPPA, but funding proved to be unavailable.

Initial work with the data collected by the 915-MHz profiler revealed the existence of second- and third-trip echoes in the spectral files during periods in which hydrometeors were present in the field of view (as determined by the vertical-beam data from the Willams/White S-band radar). It is not clear to what extent these echoes affected the resultant profiles during those periods; more work will be needed in this area. If 449-MHz winds are recovered, they could play an important role in this process.

EOP-mean daily cycles of lower-tropospheric winds and anomalous winds have been computed using the 915-MHz data. During the daytime, there was inland flow extending up to 1 km with winds aloft becoming more southerly. There was a weak land breeze at night at low levels while upper levels exhibited more transience. This pattern is in marked contrast to the daily cycle shown further north at Puerto Penasco, where the nighttime flow is dominated by a low-level jet (R.H. Johnson, 2005, personal communication).

6. ACCOMPLISHMENTS

- Identified problems in wind data collected during the EOP, as well as possible solutions.
- Produced initial description of daily cycle of lower-tropospheric flow over Estacion Obispo.
- Participated in the NAME Data Workshop and SWG-7; made connections with other researchers for future collaborations and to ensure our data are a part of any resulting data collections or assimilation efforts.
- Created the following data sets for the 2004 campaign:
  - 915-MHz wind and virtual temperature profiles
  - 2-min averages of surface meteorological parameters
  - Soil moisture, soil temperature, and ground heat flux
  - Radiative fluxes
  - Cloud base heights

7. FUTURE WORK (FY06)

- Re-deploy the ESRL measurement site in Estacion Obispo. The plan is to deploy a 915-MHz wind profiler with RASS, a 10-m meteorological tower sampling standard meteorological parameters, instrumentation for the measurement of energy balance and radiation budgets, a GPS-IPW system, a cloud ceilometer and a disdrometer. The goal is to have the site operational by 1 July and to remove the site in late September.
- Finish GPS-IPW data set from the 2004 field campaign. These data are processed by another laboratory and their schedule could not accommodate the work until this fiscal year.
- Process data from the 2005 field campaign.
- Ensure delivery of meteorological data to JOSS for archival with other NAME datasets.
- Complete analysis of daily cycle of wind and virtual temperature profiles and surface observations from Estacion Obispo; submit manuscript to Journal of Climate and present results at the 18th AMS Conference on Climate Variability and Change.
- Continue analysis of wind profiles collected during the NAME EOP at ISS sites along the Gulf of California with Dick Johnson, Paul Ciesielski, and Peter Rogers; prepare manuscript and present initial results at the 18th AMS Conference on Climate Variability and Change.
- Analyze daily cycle of wind profiles and surface observations from the R/V Altair.

8. PUBLICATIONS

Journal Articles:

Hartten, L. M., C. W. King, and R. J. Zamora, 2006: The lower troposphere's daily cycle near the mouth of the Gulf of California during NAME 2004. Submitted to *Journal of Climate (NAME Special Issue)*, October 2005.

Rodriquez-Manzanet, L.M., 2005: Lower tropospheric analysis of the daily cycle of the wind for the east coast of the Gulf of California during NAME 2004, 19 pp. (Available from SOARS, UCAR, P.O. Box 3000, Boulder, CO 80307

9. PRESENTATIONS

"Overview of wind/flux/radiation observations at the ETL/AL flux site", NAME 2004 Data Workshop, Mexico City, Mexico, L.M. Hartten.